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(54) **Method for measuring a signal transmission delay time station, terminal station and network system to perform this method**

(57) The method is used in an optical transmission network with a plurality of terminal stations (TS1-TSn) connected to a central station (CS) via a tree-like connection structure, to determine a signal transmission delay time between one terminal station (TSi) and the central station. The terminal stations are adapted to send cells containing information signals to the central station in dedicated time slots. The method consists of sending a start signal (start CR) from the central station to the terminal station (TSi), sending a first predetermined time interval after the receipt of that start signal, a ranging signal from the terminal station to the central station, sending a second predetermined time interval after the sending of the start signal an inhibit signal from the central station to the terminal stations to indicate that no cells may be transmitted during an idle time window; deducing in the central station the signal transmission delay time from contents of the predetermined ranging signal received by the central station during the idle time window. The ranging signal either has an amplitude which is smaller than the information signals contained in the cells in order not to disturb the information signals when the ranging signal is transmitted outside the idle time window, or has a similar amplitude in which case error codes are included in the cells in order to recover possible disrupted cells.

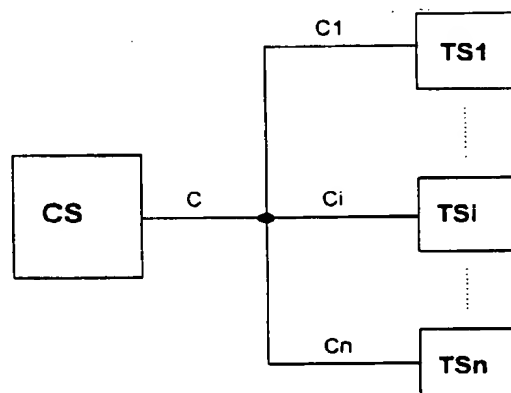


Fig. 1

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Description

The present invention relates to a method for measuring a signal transmission delay time, and to a central station, a terminal station and an optical network performing this method as described in the non characterizing part of claims 1 or 2, 11 or 12, 13 or 14, and, 15 or 16 respectively.

Such a method, central station, terminal station and network are already known in the art, e.g. from the *European Patent Application 90890273.7*. Therein an optical system is described where a terminal station becoming active can perform its ranging procedure, i.e. a procedure to determine the transmission delay between that terminal station and the central station, and additionally the procedure for obtaining its address, in a so called ranging window wherein the other terminal stations already active do not send cells to the central station. From this transmission delay the terminal station then deduces in which time slot it is enabled, after receipt of a grant signal from the central station to send its information cells. This known procedure implies that the ranging window equals at least twice the maximum transmission delay of the network since the terminal station which becomes active is not aware of the configuration of the network, i.e. it is not aware of the distance between the other terminal stations and the central station and consequently it does not know when it may send a ranging signal without disturbing the transmission of the information signals. As a result, the active terminals are not allowed to send information during a relatively long period, especially since this ranging procedure is executed periodically, either to allow activated terminals to go through a configuration phase, or to possibly adjust the already defined transmission delays of already active terminals.

An object of the invention is to provide a method, a terminal station, a central station and a network realizing this method, such as the known one but which does not represent the above drawback, i.e. where there is no need for a relatively large ranging window.

According to the invention this object is achieved by the method, the central station, the terminal station and the optical network as described in claims 1 or 2, 11 or 12, 13 or 14, and, 15 or 16 respectively.

Indeed, by either sending a ranging signal with an amplitude lower than the amplitude of the information signals or including error codes in the cells and sending a ranging signal with an amplitude near to the amplitude of the information signals, the ranging signal can be transmitted during the transmission of the information signals, i.e. outside the idle time window, called ranging window in the known method. The central station can thus open a ranging window, by asking the terminal stations to stop transmission of the information signals, during a time interval which is smaller than in the known systems, provided that that the window and the ranging signal are so chosen that at least part of the latter signal can be received during the open window, i.e. the period

of transmission of the ranging signal has at least partly to overlap the idle time window. Different choices can be made with respect to the length of the idle time window, the length of the predetermined time intervals and of the type of ranging signal. The definite choice is a trade off between the time and the bandwidth needed for performing the ranging procedure. Indeed, the larger the window, the more bandwidth is required, but the more information can be received by the central station and thus the less time is required to determine the transmission delay with a required accuracy and vice versa. A possible choice realizing a good compromise between the latter time and bandwidth requirements is disclosed in claims 6 to 10.

It has to be remarked that the use of error codes and of ranging signals having an amplitude in the range of the amplitude of the information signals is especially suited for large scale passive optical networks also called SUPERPONs with a relatively high number of terminal stations and relatively large distances between the terminal stations and the central station and having a high dynamic range, and wherein due to used amplifiers, the amplitude of the noise signals come within the range of the amplitude of a reduced amplitude ranging signal.

The above mentioned and other objects and features of the invention will become more apparent and the invention itself will be best understood by referring to the following description of an embodiment taken in conjunction with the accompanying drawings wherein:

Fig. 1 represents an optical network wherein a method according to the invention is realized; and Figs. 2a and 2b are timing diagrams of the performance of a ranging method according to the invention.

The network of Fig. 1 is a passive optical network or PON network over which Time Division Multiple Access or TDMA PON cells are transmitted. These cells (not shown) consist of a header, containing a synchronization preamble, and a data packet.

The network includes a central station CS coupled to a plurality of terminal stations TS1 to TS_n via a common fiber link C and dedicated links C1 to C_n. PON cells are transmitted over the network in downwards direction from CS to the terminal stations and in upwards direction from the terminal stations to CS in dedicated time slots. To avoid collision between the upwards sent cells, each terminal station has to be aware of its transmission delay, i.e. of the distance between itself and the central station. Transmission of upstream cells is initiated by the central station by a grant signal. Upon receipt of such a grant signal a terminal station has to take into account a predetermined delay, called ranging delay, before sending a cell to avoid the above mentioned collision. This delay is such that it is as if the terminal station was located at the maximum network distance from the central station and can be deduced from the earlier

mentioned transmission delay. The procedure for determining the transmission delay or the ranging delay, also called the ranging procedure, as used in the subject invention is described hereafter with reference to Figs. 1 and 2.

The principle of the ranging procedure is that a terminal station becoming active, e.g. TSi, sends upon receipt of a start ranging signal called start CR, a ranging signal towards CS. Depending on the type of the network, this signal is either sent out at an amplitude relatively smaller than that of the information signals included in the PON upstream cells or at an amplitude in the range thereof. In relatively small networks, where there is no need for optical amplifiers, the ranging signal is sent out at the relatively lower amplitude, which is such that there is no degradation of the information signals. However in larger networks including optical amplifiers, the resulting noise signal can have an amplitude in the range of the lower amplitude ranging signal, and therefore, the ranging signal is then generated at an amplitude in the range of the PON cell signals. In order to be able to recover the latter signals in case of possible degradation due to the transmission of the ranging signal, Forward Error Correction coding such as the Reed Solomon coding, is included in the cells. Use of such error codes in transmission systems is well known in the art and is therefore not described in details.

A predetermined period after the sending of the start CR signal, CS sends a inhibit signal to the other terminal stations to stop the sending of cells during a well defined time interval, also called ranging window, which is smaller than the time interval during which the ranging signal is transmitted by TSi. Upon receipt of the ranging signal during the ranging window, CS determines based on the contents of the signal, a first evaluation of the transmission delay of TSi, as will be described hereafter, and transmits the thus obtained evaluation of the transmission delay to TSi. The ranging procedure is possibly repeated a predetermined number of times to more accurately evaluate this transmission delay. However, during those repetitions, the ranging signal is not sent out upon receipt of the start CR signal but a predetermined time interval thereafter. This time interval equals a ranging delay deduced from the previously evaluated transmission delay. As will be explained hereafter, the ranging signal, which consists of a number of repeated sequence numbers contained in this signal, is adapted accordingly. The complete procedure is additionally repeated on a periodic basis whilst TSi is active, to possibly adjust the determined transmission delay. In order to clarify how the value of the parameters used in the ranging procedure such as the time interval between the sending of the start CR and the signal to inhibit the sending of cells and the type of ranging signal are chosen, a description is given hereafter of a ranging procedure applied to a specific example to which Fig. 2 is applicable.

A network of maximum length of 4 cells is considered.

As already mentioned earlier, the ranging signal consists of subsequently sent ranging messages. These messages are sent with a cell frequency and include subsequent sequence numbers. For a network with a maximum length of 4 cells and choosing a maximum sequence number of 2, the ranging window has at least to be opened during the 8th cell after the transmission of the start CR signal to take into account a possible location of a terminal station performing the ranging procedure at the maximum distance from the central station. However, in order to see at the central station possible sequence transitions, a window of 2 cells, i.e. the 8th and the 9th cell after the start CR, is opened. As a result, the ranging signal has to consist in a first execution of the steps of the method of 8 ranging messages, 4 with sequence number 1 and 4 with sequence number 2, to take into account a possible location of the terminal station at a minimum distance from the central station. In this example the ranging procedure is performed by a terminal station TS located within the first cell from the central station. This means, as can be seen in Fig. 2a, that the terminal station receives the start CR after an interval smaller than 1 cell and that the ranging signal, or more specifically the first message thereof is received by the central station between 1 and 2 cells after the latter start CR signal. As a result, the central station sees in the ranging window 2 times a sequence number 2, from which it can be deduced that the terminal station is located in the first half of the network, i.e. between 0 and 2 cells away from that central station.

This is communicated to the terminal station, which in a second step, i.e. after receipt of a second start CR signal, supposes it is located 2 cells away from the central station and waits for its first evaluated ranging delay of $2 \times (4-2) = 4$ cells before transmitting the ranging signal. This ranging signal then consists of the sending of 4 ranging messages, 2 with sequence number 1 and 2 with sequence number 2. The open window again includes the 8th and 9th cell after the start CR and as a result, the central station again sees 2 time the sequence number 2 as can be seen in Fig. 2b, meaning that the terminal station is located within the first half of the network, i.e. within 1 cell from the central station. In this way, the transmission delay of the station is determined with an accuracy of 1 cell.

It has to be remarked that had the terminal station been located in the second part of the network, then it had supposed to be located 4 cells away from the central station and it would in a second step of the ranging have sent out a ranging signal immediately after the receipt of the start CR.

Generalizing the above description, the parameters for the subject ranging method can be defined as follows.

Assuming that L is the number of upstream cells corresponding with twice the maximum difference in transmission delay between two terminal stations, i.e. twice the maximal distance between the central station

and a terminal station, and 2^n being the maximum sequence number, then a terminal station has to send after the first start CR:

m times the sequence number 1;

...

m times the sequence number 2^n , where $m = L/2^n$.

The central station opens a ranging window of 2 cells during the Lth and the L+1th cell. The sequence number read in this window gives the transmission delay with an accuracy of $L/2^n$. As such, the measurement must be repeated $L/2^n$ times, with m being in the subsequent steps divided by 2, in order to determine the transmission delay with a cell accuracy.

To be noted that the maximum sequence number can be chosen in different ways. The higher this maximum number the more accurate the ranging delay can be determined, but the longer the ranging signal becomes since then more bits are needed to specify the sequence numbers

In an alternative method, instead of waiting for a time interval equal to a coarse ranging delay, when the latter is known, the ranging signal can in the repetitions of the steps as described above be sent out immediately after the receipt of the start CR, and the central station can rely upon the fact that no ranging message is received in at least part of the ranging window to more accurately determine the transmission delay.

It has also to be remarked that in order to be able to perform the above described ranging method, the terminal station as well as the central station have to be aware of the value of L and of the chosen maximum sequence number, which have thus to be preconfigured in these latter stations.

Since it is obvious for a person skilled in the art to implement a central station and a terminal station based on the above functional description of the steps to be performed to realize the subject ranging procedure, and based of the already known implementations of central stations and terminal stations, these stations are not described herein in further details.

While the principles of the invention have been described above in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation on the scope of the invention.

Claims

1. Method for measuring in an optical transmission network with a plurality of terminal stations (TS1 - TSn) connected to a central station (CS) via a tree-like connection structure, a signal transmission delay time between one terminal station (TSi) of said plurality of terminal stations and said central station, said terminal stations being adapted to send cells containing information signals to said central station in dedicated time slots, said method including the step of sending a predetermined rang-

ing signal from said one terminal station to said central station for receipt in an idle time window during which no said cells are transmitted, characterized in that said method additionally includes the steps of:

- sending a start signal (start CR) from said central station to said one terminal station (TSi);
- sending a first predetermined time interval after the receipt of said start signal, said predetermined ranging signal from said one terminal station to said central station, said predetermined ranging signal having an amplitude which is smaller than the amplitude of said information signals, thereby avoiding degradation of said information signals due to the transmission of said predetermined ranging signal outside said idle time window.;
- sending a second predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during said idle time window;
- deducing in said central station said signal transmission delay time from contents of said predetermined ranging signal received by said central station during said idle time window.

2. Method for measuring in an optical transmission network with a plurality of terminal stations (TS1-TSn) connected to a central station (CS) via a tree-like connection structure, a signal transmission delay time between one terminal station (TSi) of said plurality of terminal stations and said central station, said terminal stations being adapted to send cells containing information signals to said central station in dedicated time slots, said method including the step of sending a predetermined ranging signal from said one terminal station to said central station for receipt in an idle time window during which no said cells are transmitted, characterized in that said terminal stations are able to include error codes in said cells and that said method additionally includes the steps of:

- sending a start signal (start CR) from said central station to said one terminal station (TSi);
- sending a first time interval after the receipt of said start signal, said predetermined ranging signal from said one terminal station to said central station, said predetermined ranging signal having an amplitude relatively near to the amplitude of said information signals;
- sending a second predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during

said idle time window;

- deducing in said central station said signal transmission delay time from contents of said predetermined ranging signal received by said central station during said idle time window 5

said error codes and said predetermined ranging signal being so chosen as to enable recovery of said information signals in case of corruption by said predetermined ranging signal sent outside said idle time window. 10

3. Method according to claim 1 or 3, characterized in that said first predetermined time interval equals a previously determined coarse value of said signal transmission delay time, said steps then being performed to obtain a more accurate value thereof. 15
4. Method according to claim 1 or 2, characterized in that said first predetermined time interval equals zero. 20
5. Method according to claim 1 or 2, characterized in that said predetermined ranging signal is composed of repetitive signals including successive integer values. 25
6. Method according to claim 1 or 2, characterized in that in a first application of said steps where said first predetermined time interval equals zero, the length of said predetermined ranging signal equals L, where L equals two times the maximum possible difference in transmission delay between two said terminal stations. 30
7. Method according to claim 5, characterized in that said second predetermined time interval equals L-1 cells, where L equals two times the maximum possible difference in transmission delay between two said terminal stations. 35
8. Method according to claim 7, characterized in that each of said successive integer values is transmitted m times where m equals $L/2^n$, 2^n being the maximum value of said successive integer value. 40
9. Method according to claim 8, characterized in that said idle time interval equals 2 said cells and that said repetitive signals are transmitted at cell rate. 45
10. Method according to claim 9, characterized in that said steps are repeated $L/2^n$ times, the length of said repetitive signal being divided by 2 in each repetition, thereby enabling to determine said signal delay time with the accuracy of one said cell. 50
11. Central station (CS) adapted to be included in an optical network with a plurality of terminal stations (TS1 -TSn) connected to said central station via a

tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said central station including means to receive a predetermined ranging signal from one terminal station of said plurality of terminal stations in an idle time window during which no said cells are transmitted, characterized in that said central station additionally includes:

- means to send a start signal (start CR) from said central station to said one terminal station;
- means to send a predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during said idle time window;
- means to deduce a signal delay time between said one terminal station and said central station from contents of said ranging signal received by said central station from said one terminal station during said idle time window.

12. Central station (CS) adapted to be included in an optical network with a plurality of terminal stations (TS1-TSn) connected to said central station via a tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said central station including means to receive a predetermined ranging signal from one terminal station of said plurality of terminal stations in an idle time window during which no said cells are transmitted, characterized in that said central station additionally includes:

- means to send a start signal from said central station to said one terminal station;
- means to send a predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during said idle time window;
- error recovery means to interpret error codes included in said cells and to recover said information signals in case of corruption by said information signals due to the transmission of said predetermined ranging signal outside said idle time window;
- means to deduce a signal transmission delay time between said one terminal station and said central station from contents of said ranging signal received by said central station from said one terminal station during said idle time window.

13. Terminal station (Tsi) adapted to be included in an

optical network with a plurality of terminal stations (TS1-TSn) similar to said terminal station and connected to a central station (CS) via a tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said terminal station including means to send a predetermined ranging signal to said central station for receipt in an idle time window during which no said cells are transmitted, characterized in that said terminal station additionally includes:

- means to receive a start signal (start CR) from said central station to said terminal stations and to send out said predetermined ranging signal a predetermined time interval after the receipt of said start signal, said predetermined ranging signal having an amplitude which is smaller than the amplitude of said information signals, thereby avoiding degradation of said information signals due to the transmission of said predetermined ranging signal outside said idle time window.

14. Terminal station (TSi) adapted to be included in an optical network with a plurality of terminal stations (TS1-TSn) similar to said terminal station and connected to a central station (CS) via a tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said terminal station including means to send a predetermined ranging signal to said central station for receipt in an idle time window during which no said cells are transmitted, characterized in that said terminal station additionally includes:

- means to receive a start signal (start CR) from said central station to said terminal stations and to send out said predetermined ranging signal a predetermined time interval after the receipt of said start signal, said predetermined ranging signal having an amplitude relatively near to the amplitude of said information signals
- means to include error codes in said cells.

15. Optical network with a plurality of terminal stations (TS1-TSn) connected to a central station (CS) via a tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said central station including means to receive a predetermined ranging signal from one terminal station (CSi) of said plurality of terminal stations in an idle time window during which no said cells are transmitted and said terminal stations including means to send said predetermined ranging signal, characterized in that said

central station additionally includes:

- means to send a start signal (start CR) from said central station to said terminal stations;
- means to send a first predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during said idle time window;
- means to deduce a signal transmission delay time between said one terminal station and said central station from contents of said ranging signal received by said central station from said one terminal station during said idle time window; and

in that said terminal stations additionally includes:

- means to receive said start signal from said central station to said terminal stations and to send out said predetermined ranging signal a second predetermined time interval after the receipt of said start signal, said predetermined ranging signal having an amplitude which is smaller than the amplitude of said information signals, thereby avoiding degradation of said information signals due to the transmission of said predetermined ranging signal outside said idle time window.

16. Optical network with a plurality of terminal stations (CS1-CSn) connected to a central station (CS) via a tree-like connection structure, and wherein said terminal stations are adapted to send cells containing information signals to said central station in dedicated time slots, said central station including means to receive a predetermined ranging signal from one terminal station (Csi) of said plurality of terminal stations in an idle time window during which no said cells are transmitted and said terminal stations including means to send said predetermined ranging signal, characterized in that said central station additionally includes:

- means to send a start signal (start CR) from said central station to said terminal stations;
- means to send a first predetermined time interval after the sending of said start signal an inhibit signal from said central station to said terminal stations to indicate to said terminal stations that no said cells are to be transmitted during said idle time window;
- error recovery means to interpret error codes included in said cells by said terminal stations and to recover said information signals in case of corruption of said information signals due to the transmission of said predetermined ranging

signal outside said idle time window;

- means to deduce a signal transmission delay time between said one terminal station and said central station from contents of said ranging signal received by said central station from said one terminal station during said idle time window; and

in that said terminal stations additionally includes:

- means to receive said start signal from said central station to said terminal stations and to send out said predetermined ranging signal a second predetermined time interval after the receipt of said start signal, said predetermined ranging signal having an amplitude relatively near to amplitude of said information signals
- means to include said error codes in said cells.

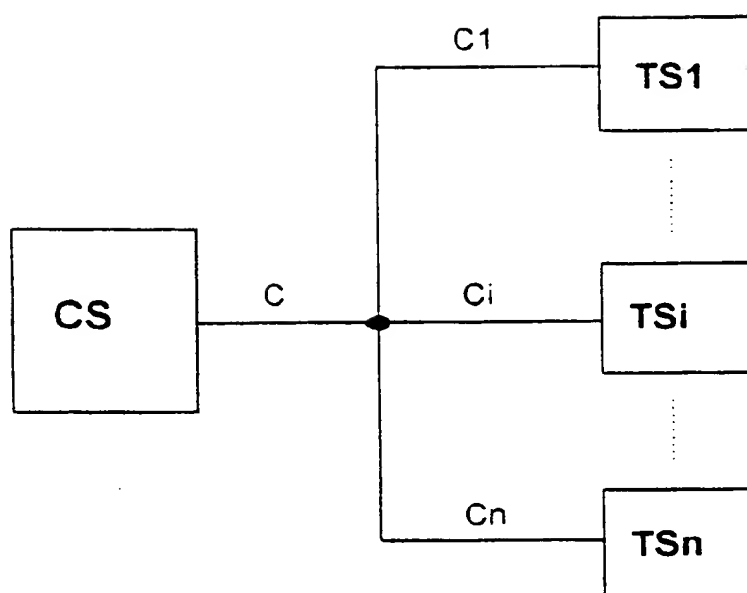


Fig. 1

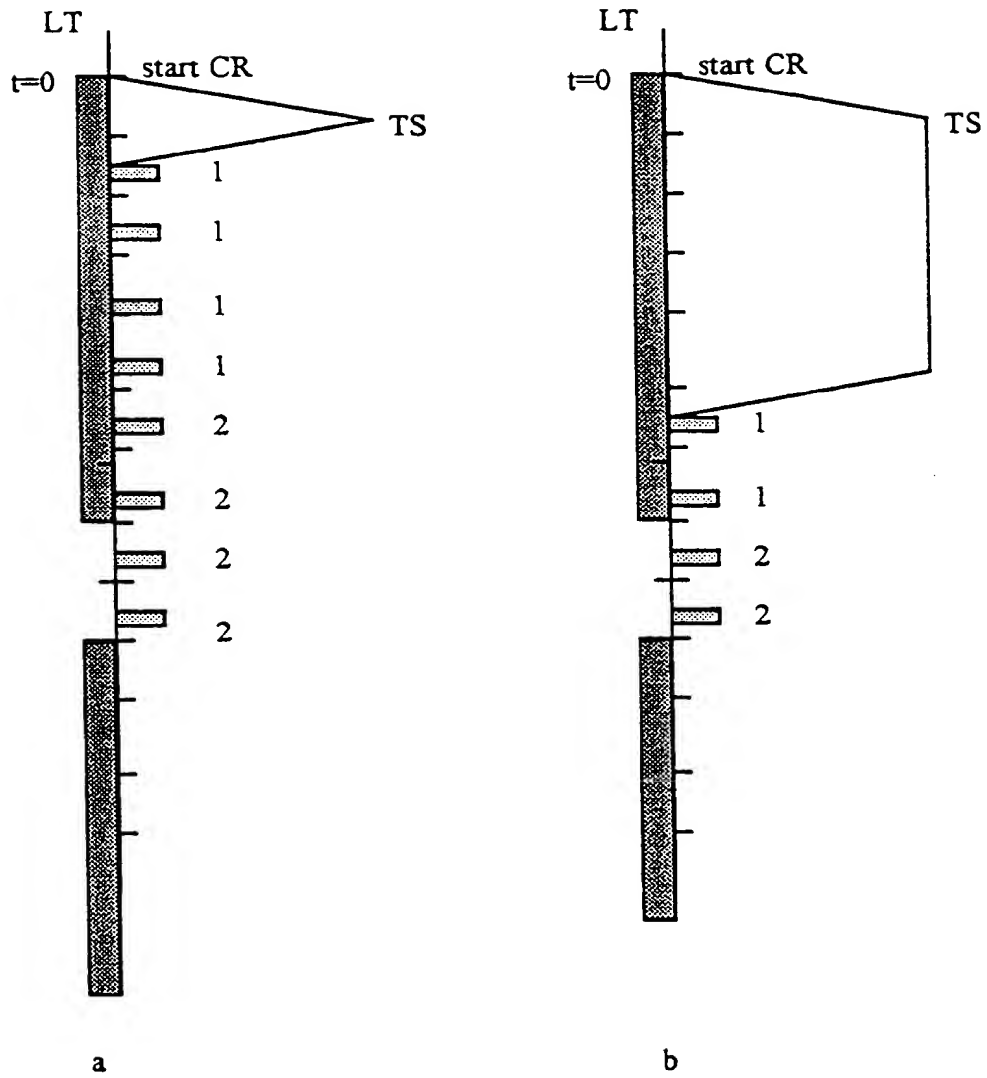


Fig. 2



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EUROPEAN SEARCH REPORT

Application Number
EP 95 20 2555

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	EP-A-0 616 443 (PHILIPS NV) 21 September 1994 * page 5, line 8 - line 17 * * page 6, line 3 - line 5 * * page 6, line 21 - line 33 *	1-4, 11-16	H04B10/207 H04J3/06
A	* page 6, line 50 - line 58 * * claims 1,9; figures 1,5 *	5-10	
Y	CABLE TV SESSIONS, MONTREUX, JUNE 13 - 18, 1991, no. SYMP. 17, 14 June 1991 CCITT, pages 97-107, XP 000260033 VAALEN M J M VAN 'ASYNCHRONOUS TRANSFER MODE TRANSMISSION ON A PASSIVE OPTICAL HOME NETWORK' * page 103, paragraph 2 - page 104, paragraph 1 * * page 105, paragraph 3 * * page 106, paragraph 2 * * figures 4,7 *	1-4, 11-16	
A	EP-A-0 521 197 (ALCATEL NV ;BELL TELEPHONE MFG (BE)) 7 January 1993 * column 1, line 1 - line 8 * * column 1, line 35 - line 38 * * column 2, line 14 - line 29 * * column 5, line 47 - column 6, line 14 * * column 8, line 36 - column 9, line 34 * * figures 1-3 * --- -/--	1-4,9, 11-16	TECHNICAL FIELDS SEARCHED (Int.Cl.6) H04J H04L
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 5 March 1996	Examiner Pieper, T
<p>CATEGORY OF CITED DOCUMENTS</p> <p>X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure F : intermediate document</p> <p>T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons ----- & : member of the same patent family, corresponding document</p>			

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EUROPEAN SEARCH REPORT

Application Number
EP 95 20 2555

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
A	IEICE TRANSACTIONS ON COMMUNICATIONS, vol. E75 - B, no. 9, 1 September 1992 pages 841-848, XP 000321319 KAZUHISA KAEDE ET AL 'A PASSIVE DOUBLE STAR OPTICAL SUBSCRIBER SYSTEM WITH FREQUENCY DIVISION DUPLEX TRANSMISSION AND FLEXIBLE ACCESS' * page 844, left column, paragraph 3.4; figures 6,7 *	1,2. 11-16	
A	ELECTRONICS & COMMUNICATIONS IN JAPAN, PART I - COMMUNICATIONS, vol. 73, no. 5, May 1990 NEW YORK US, pages 99-108, XP 000159285 T. KITAMI 'Synchronization Method Employing Cyclic Redundancy-Check in Asynchronous Transport System' * abstract *	2,12,14, 16	
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The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 5 March 1996	Examiner Pieper, T
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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